Report Title: First Responder Immersive Training Environment (FRITSE): Development of a Games-Based Simulator for CBRN First Responder Training.

Contract Number: W7702-125298/001/SV

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Final Contract Report

Defence Research and Development Canada
Contract Report
DRDC-RDDC-2014-C318
November 2014

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1. Introduction

Chemical, Biological, Radiological-Nuclear and Explosives (CBRNE) pose a real threat to Canadians and indeed to North Americans. The events of September 11th, 2001 prove that we are not immune to terrorist attacks, and that our lives and psychological well-being can be destroyed in an instant when one of these attacks is executed on Canadian and/or North American soil. The Chemical, Biological, Radiological-Nuclear and Explosives Research and Technology Initiative (CRTI) has been conceived to make Canada much more prepared for these types of attacks so that prevention as well as response measures can be taken to reduce the damage that will inevitably be sustained. This initiative calls for the development of realistic training to prepare first responders for such situations so that they can respond promptly, correctly and effectively.

3DInternet in collaboration with its various partners, have developed a highly realistic synthetic environment (SE), using leading edge game development techniques. This multi-user response training tool is both challenging and engaging to the end users which consist of first responders, emergency managers and incident commanders. Using Geographic Information Systems (GIS) data, a quadrant of downtown Calgary has been modeled in detail so that users can navigate this section during a hazardous train derailment scenario with secondary van explosion. Using the plume evolution data provided by one of our project partners Dr. Fue-Sang Lien (Waterloo CFD Consulting Inc. or WATCFD) and obtained using physics-based models for plume dispersion in a built-up environment, virtual hazardous agents within the SE evolve realistically through the buildings making up the Calgary city core. The realistic time and spatial development of the hazardous plume in the complex urban environment allow first responders and emergency managers to be trained within the SE to correctly respond to and manage these types of hazards.

The following sections within this report outline the work that has been performed so far in regards to the SE, and all the functionality that has been developed to provide a prototype of a games-based synthetic environment for CBRNE training of first responders and incident commanders.

2. Work Completed

2.1. Plume Modeling

The gigabytes upon gigabytes of plume data provided to 3DInternet for use within the virtual reality CBRNE training environment has been used in two ways. The first is to provide a real-time "visualization" to the user. The user can click on the icon for "plume visualization" to see the current state of "all" plumes currently in-effect within a simulated CBRNE incident. Each plume provides 4 visualizations of the data in a "quad-view". These are: east, south, perspective and overhead (see Figure 1).

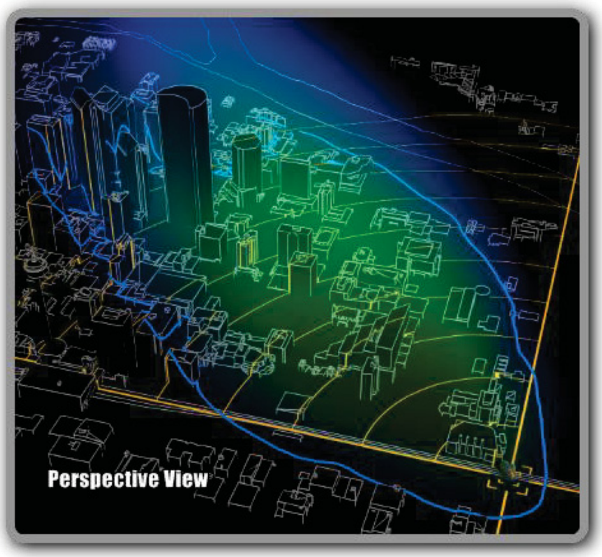

Figure 1 - The perspective plume visualization of the train derailment.

The most important thing when trying to visualize the motion of real world plume data is preserving the message that the data represents. In other words, various factors in displaying the data can themselves inadvertently affect the way the data is shown to the audience. Or, other factors can actually detract from clearly seeing what the data shows. A number of these factors have been identified and addressed in our plume data rendering to make the visualization derived from it as complete and as informative as possible.

The plume data is also "sampled" during the simulation of the CBRNE incident to determine if people (pedestrians and first responders) are within a hazard area. In order for the data to be sampled in real-time it had to be heavily optimized to fit within the primary memory of the computer, in such a way so that it could be sampled very quickly and often.

The optimization process for the plume visualization included:

- Down sampling the combination of plume and puff data for high accuracy measurements close to the ground surface, and lower accuracy on top of buildings.
- Compressing the down sampled results.
- Building a content table for reducing the delay time in accessing any specific time slice.
- Using minimum computational resources within the SE to read and decompress the requested data.

- Predicting the toxicity level of undefined positions such as underground road ways and places outside of the plume data area, by using existing plume data information in conjunction with appropriate interpolation and extrapolation schemes.

2.2. Rendering Downtown Calgary

With so large an area to be visible during the simulation of a CBRNE incident in an urban environment, optimization is imperative in ensuring smooth frame rate during operation of the SE (Figure 2). One of the key ways of reducing the size of the project was the reusing of textures across the buildings in the scene. For instance, using the same brick texture across multiple buildings allowed the saving of texture memory. Another way of optimizing the visualization of the urban environment was to create LOD (Level of Detail) models. The LOD models consist of a series of models of the urban environment at various resolutions and concomitant detail of representation of urban structures with the result that lower or higher resolution representations of the urban structures can be swapped in or out in accordance to the "distance" from the perspective of the player viewing the environment. This optimization method saves both polygon and texture data by using these simpler (lower resolution) models when the player is far enough away from the model to not be able to tell the difference between the two. The most important of all optimizations amidst the high quality of image we have accomplished is due to carefully constructed shaders, which were hand written and optimized to achieve the most quality with the least amount of computations. In these ways, among others, we have accomplished the visual quality which has been demonstrated in the SE.

Figure 2 - Real-time rendering of downtown Calgary, looking at the Enmax District Energy Centre.

2.3. Multi-User Capability

Multi-user capability was built into the SE right from the initial design of the product. An infrastructure has been created that will allow a PC to act as a "host" for a multi-user session and for other PC's to connect to the host as "clients". There is virtually no limit to the number of concurrent multi-user sessions which can run since there isn't a "centralized" server storing the position, orientation, and state of objects within the SE. Instead, this information is "scattered" across multiple hosts. Each PC running the SE

(both hosts and clients) provide the IP address or domain name of a “Master Server”. The Master Server maintains a list of all created “sessions” and the hosts of all those sessions. When “creating” a session, both the name and password for the session are required to create the session, and these in turn are sent over to the Master Server. When “joining” a session, the Master Server is polled for all running sessions and a list is provided to the user. The user can select the session to join and will be required to provide a password for that session.

As an example: Training Facility Y is using the FRITSE to prepare their first responders. A large room has been setup with 16 computers. The “supervisor” has his own PC and is running the Master Server. Four sessions are currently running, with 4 first responders working together within each of the 4 sessions (16 first responders in total). All 16 machines have designated the supervisor’s machine as the Master Server. The supervisor is looking at the Master Server graphical user interface and can clearly see that there are 4 sessions running. He can also look into each of the individual sessions and see which users comprise those sessions.

The Master Server has been enhanced to include a “Real-Time Supervisory Control” or RTSC (see Figure 3). Currently, the RTSC allows the supervisor to see a top-down view of the Calgary downtown area using GIS Mapping Technology. Each running session has its own tab with embedded GIS Information. The supervisor can see all pedestrians, vehicles, first responders and first responder vehicles in the GIS view. Changes within the SE of a session, such as the movement of objects (people and equipment), updates the corresponding GIS view within the RTSC of the Master Server.

Figure 3 - Screen capture of the Real-Time Supervisory Control.

The RTSC can potentially provide a large amount of control to the supervisor in triggering events within the Simulation. These include but are not limited to:

- Causing people to collapse out of shock, or causing people to react in stress induced ways.
- Creating vehicular accidents in response to chaos.
- Causing other explosions – e.g., a fertilizer bomb outside the downtown municipal building.
- Changing the wind direction.
- Modifying available resources such as first responders and rigs.

2.4. Controlling and Manipulating Objects

Early on it was decided that all object interaction would occur using the "Actions Menu" (see Figure 4). A user can "look" at an object and then options for how to control that object or communicate with it will appear within the Actions Menu. For example, looking at a pedestrian will provide options for communicating with that pedestrian. A pedestrian can be asked if they are ill or can be instructed to follow the user to decontamination. Looking at a fire hydrant, the user can turn the stem on top of the hydrant or remove the steamer cap / discharge caps (assuming the user is holding a nozzle wrench in his hand). Looking at a trauma bag or hydrant bag allows the user the option to pick these up and walk to another area of interest, or to open them up to see what is inside.

Figure 4 - Looking at the trauma bag. Actions menu shows control options.

2.5. Communication

Users have the ability to communicate with other first responders (emergency medical services (EMS), police, and firefighters) as well as pedestrians. Again, all communication actions take place within the Actions Menu as shown in Figure 5. The user can look at a first responder or pedestrian and then options for what words should be communicated appear within the Actions Menu. A variety of dialogs can be communicated; it is a simple matter of selecting the appropriate one from the list and then filling in missing pieces using drop-down lists. Once the desired dialog has been selected, it can be spoken using the text-to-speech engine available in Windows. Users can also communicate with other first responders using the portable radio which they carry. In this case they do not have to be "looking" at another first responder. They simply click the "Speak into Portable Radio" button in the Actions Menu.

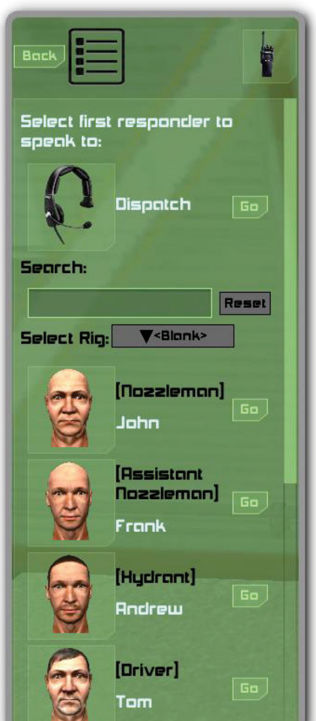

Figure 5 - Actions menu showing communication options.

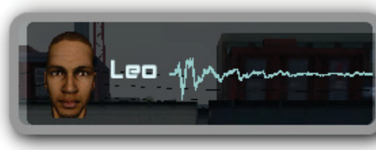

Figure 6 - On-screen VoIP GUI.

In a multi-user session, "real-users" in addition to using the dialog options within the Actions Menu (for face-to-face as well as portable radio communication) are able to use the built-in voice over IP (see Figure 6). Only one person is able to use the voice over IP channel at a time. Holding down the 'P' key opens up the channel for communication, and the user is able to start speaking through their microphone. The "other users" within the multi-user session can hear the speaker through their headsets. The heads-up-display within the SE clearly shows who is using the voice over IP channel.

2.6. Artificial Intelligence

Figure 7 - Showing decontamination setup with high volume - low pressure water.

During the course of the simulation of a hazardous release incident, several rigs (apparatus) are required to complete the stages of decontamination and attack of the train derailment fire. These include the Fire Engine, Aerial Ladder Truck, Hazmat and District Chief Van. Each of these rigs can have anywhere from 1 – 5 responders within them. If we factor in police and EMS, then during the simulation a user could possibly encounter 25 other first responders. First responders which are not controlled by a "real-user" are controlled by artificial intelligence (AI) instead. Within the framework of the Simulation Engine these entities are known as NPCs or "non-player characters". Each of these maintains an internal "task list", and performs tasks in a linear fashion. When playing the role of a Captain, a user can instruct an AI controlled first responder to perform certain tasks such as:

- Putting on their (Self-Contained Breathing Apparatus) SCBA and face-piece.
- Putting on their firefighter jacket and pants.
- Positioning cones to delineate an area for conducting decontamination (see Figure 7).
- Spraying high-volume / low pressure water on incapacitated persons possibly contaminated with a chemical agent (see Figure 8).
- Bringing an incapacitated person into the decontamination area.

Figure 8 - Firefighters positioning cones in the decontamination area.

This has the direct affect of adding a "task" to the NPCs internal tasks list. A "task" is programmed to implement a specific interface, so there are a group of functions which

are "common" to all tasks. This makes programming additional tasks and maintaining existing tasks easier. Using this framework a "library" of tasks has been created which can be performed by any first responder (firefighter, EMS and police).

2.7. Pedestrians and Vehicular Traffic

Figure 9 - Real-time rendering of pedestrians.

Pedestrians and vehicular traffic have been added to the 3D representation of downtown Calgary. Pedestrians are critical to the training functionality of the SE as they interact with the plume model in real-time by displaying the symptoms of a possible exposure to a hazardous material, as well as being an integral part of decontamination and subsequent treatment of exposure to the hazardous material. Pedestrians walk along paths inside of downtown Calgary. They traverse a network of waypoints and create the illusion that they have "places to go and people to meet". When navigating towards a specific waypoint, the pedestrian will pick a "point" x units away from the waypoint in a random (x, y) direction. Think of this as a random point on the circumference of a circle x units in radius. Algorithms of this nature allow multiple pedestrians walking to the same point to take slightly different paths instead of walking in a robotic line. When pedestrians encounter injured people (as a result of hazard material exposure or other causes) along their route they may try to help. However, if lots of pedestrians are currently helping an injured person, they may carry on without stopping.

Vehicular traffic has been added for additional realism. They bring life to the city and also act as occasional annoyances when first responder vehicles are attempting to navigate the city and arrive at staging areas.

2.8. Treating Injured Persons

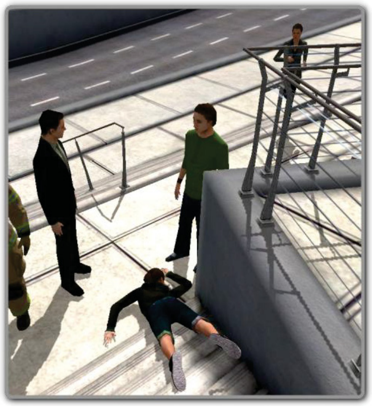

Figure 11 - Real-time rendering showing a collapsed pedestrian who has suffered a heart attack.

The train derailment explosion causes injuries to a number of people on the south and north side of the 4th street underpass. Some of these injured people have suffered minor head trauma and others have suffered major head trauma. Other pedestrians will naturally be concerned about these injured people if they encounter them, and will stop to see if they can help. If a first responder is on scene and is within view of a concerned pedestrian, the pedestrian will run to the responder and notify him / her that someone is hurt and requires medical intervention. As always, the user (playing the role of a first responder) can decide the desired course of action. He / she can pick up a trauma bag from a Fire Engine and then approach an injured person lying on the ground. The injured person can be repositioned (while their heads are being supported) and a variety of diagnostic tests can be performed according to the user's discretion. Pupil dilation, blood pressure, pulse and respiration can all be assessed by the first responder see Figure 10). Additionally, there are instances where a pedestrian has collapsed due to cardiac arrest and will need to be resuscitated using an automatic defibrillator which is also available in the Fire Engine (see Figure 11).

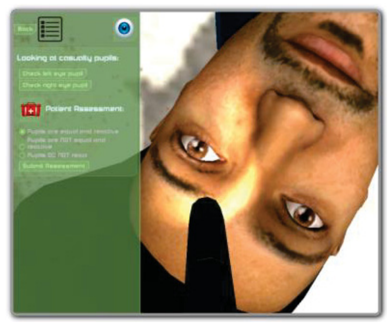

Figure 10 - First responder is checking an injured person's pupil dilation.

2.9. Decontamination

Two key events have been built into the SE: the initial train derailment, and the van explosion possibly releasing an unknown hazardous agent which occurs approximately 15 minutes later. The hazardous agent which is released into the surrounding area causes severe symptoms in the people (pedestrians and first responders) which it encounters. People exposed to the effects of the hazardous agent are eventually overcome with symptoms of drooling, discharge from the eyes / nose, heavy breathing and coughing. Without immediate first responder intervention, these affected people may die. Playing the role of Captain, a user can instruct other first responders to setup their rigs for decontamination and treatment.

Figure 12 - Real-time rendering showing a first responder communicating with a pedestrian that has been exposed to a hazardous agent.

Fire Engines, Aerial Ladder Trucks and Hazmat can be utilized for the decontamination setup. Next, the Captain can instruct first responders to start laying out cones which will be used to guide the possibly contaminated people through the rigs so that high-pressure / low volume water can be sprayed on them to “clean” them. The Captain can also instruct first responders to start locating other people incapacitated within “hot zones”, and start guiding them through the decontamination process. As a first responder, the user is able to communicate with people suffering from hazardous material intoxication directly to assess their condition (see Figure 12). They can have them follow them to the decontamination area, have them remove their clothing, and then instruct them to walk though the pylons towards the other side where they will be checked. Dispatch can be contacted via the portable radio and a request can be made for transit buses. A maximum of 5 can be deployed to the decontamination area. Once checked over by Hazmat and then EMS, the affected person will be provided a yellow blanket and will be instructed to take a seat in one of the transit buses (see Figure 13).

Figure 13 - Real-time rendering showing a person possibly exposed to a hazardous agent, walking to a transit bus after being checked by EMS.

2.10. Fire Incident

Playing the role of Captain, the user can choose to start fighting the fire that may be due to the train derailment. Or the user can focus on treating injured people and then focus efforts on decontamination and possible treatment. Alternatively, the user can call in a second alarm and have one team focus on decontamination and the other team focus on fighting the train derailment fire. It is in the hands of the Captain, acting as Incident Commander, to decide what actions need to take place and when, and what the priorities are.

Figure 14 - Real-time rendering showing the view of the train derailment using field glasses.

First responders are able to perform a variety of actions in response to the train derailment fire (see Figure 14):

- Rigs can be staged at certain areas to fight the fire.
- Pony lines at the rear of the Fire Engines can be dragged over to fire hydrants to be attached to the steamer caps.
- Bolt cutters can be used to cut holes in fences allowing better access to the train derailment fire.
- Ground monitors (for blitz fire) can be positioned for fire attack.
- 65mm attack lines can be dragged from fire engines and connected to ground monitors.
- Levers at the rear cabin of the Fire Engines can be manipulated to open / close water valves.
- Nozzle wrenches can be used to open / close steamer and discharge caps on fire hydrants.
- Hydrant gate valves can be attached to fire hydrants.
- The stem on-top of the fire hydrants can be opened / closed with nozzle wrenches.
- Ground monitors can be controlled to start shooting water. Vertical angle, jet / fog control, and water pressure can be adjusted.

Figure 15 - Real-time rendering showing a ground monitor with 65mm attack line attached.

As a first responder, ground monitors can be positioned and oriented to shoot water at the train derailment fire. Fire hydrants can be setup and connected to nearby Fire Engines. After 65mm attack lines are dragged from the Fire Engine and connected to the ground monitors, the first responder can then pull the levers on the ground monitors to start shooting water at the fire (see Figure 15). The train derailment fire will respond to each stream of water that is making contact with it. After two streams of water the train derailment fire

will noticeably start to die down, and after four streams of water the fire will eventually be put out completely.

The 130mm (pony line), 65mm attack line and 44mm attack line hoses are "dynamic" and respond to the movements of the user (see Figure 16). Sophisticated algorithms using spline computations for the positioning of the hose, and skeletal animation computations to control the deformation of the hoses have been used. These result in hoses which can be dragged by the user and maintain a fixed length as defined by the programmer. As the user drags the hose end farther and farther away from its point of origin, the hose will realistically uncoil and straighten just like it does in real-life.

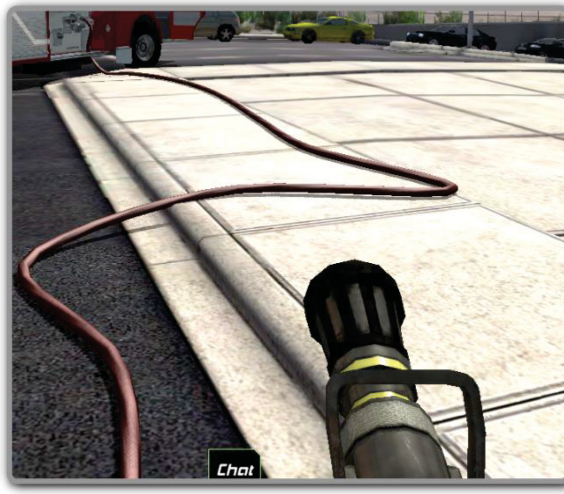

Figure 16 - Real-time rendering showing a first responder holding a 44mm attack line with nozzle.

2.11. Reporting

Figure 17 - An example of a report card after a training session.

Users can terminate the scenario and view a report of all actions which have been performed by clicking on the checkered flag icon. All actions which occur in the SE by real-players and AI players are sent over to the Reporting System built into the SE. The Reporting System assesses all actions to make sure they are complete and have been performed at the correct moments. As an example, let us imagine that the user is checking the pupil dilation of an injured person. The user can use this information along with other diagnostic tests, to

determine if the injured person has suffered a major head trauma. The user can assess the injured person and submit an assessment (see Figure 17) which then gets sent to the Reporting System. If the injured person has been assessed incorrectly then this will be shown within the report. Additional grading requirements can be built into the Reporting System depending upon the organization.

Additionally, items within the report card can be filtered based on actions performed only by real-players and actions performed only by the users themselves. Items can also be filtered so that only actions which were performed incorrectly and result in point deductions, are shown to the user. All action items within the report are time stamped, and more information about a particular item can be gathered by clicking on the “More Info” button. Going back to the incorrectly assessed pupil dilation of an injured person, the user can click the “More Info” button for this item to see exactly what was wrong with the submitted assessment.

3. Future Work

3.1. Enhancements to the Real-Time Supervisory Control

The Real-Time Supervisory Control or RTSC, allows for an Instructor / Supervisor to observe the movement of all entities in a top-down view of the City. Similar to a Google Maps view, layers built into the RTSC allow groups of entities to be toggled on / off. We propose that additional functionality be built into this tool to allow Supervisors to create events and circumstances within the Simulation during runtime. This will offer an additional tier of non-determinism within the Simulation. Supervisors will be able to cause van explosions, create traffic jams, create additional crowds of people and create additional injured persons on the fly. While creating new events and conditions in real-time, Supervisors will be able to assess whether or not participants are acting appropriately, and whether incident command is assessing the situation accurately and making the right decisions at the right moments.

3.2. Improvements to the Task-Based Artificial Intelligence Framework

The Task-Based Artificial Intelligence Framework is used by NPC (non-player characters) within the SE. These AI controlled responders maintain a list of "tasks" which they have been instructed to perform. A task can be locating the nearest first responder rig to put on SCBA, or locating an injured person in the hot-zone and guiding them to decontamination. An entire library of "tasks" can be programmed to give first responder AI characters additional behaviors and capabilities. A "Captain" or "Incident Commander" is able to delegate tasks to first responders using the Task-Based Artificial Intelligence Framework. The framework itself maintains the library of tasks and those methods / functions which "execute" the tasks. The entire framework is highly extendable and has been designed so that adding additional tasks and behaviors is straightforward and intuitive for Programmers. We need to build upon the framework to allow Incident Commanders to be able to delegate tasks regardless of whether their machine is acting as a host (created a session) or a client (joined a session). We also have to implement "task clean-up" so that if a first responder is performing a task such as placing cones in the decontamination area, and they are asked to perform another task as a priority, that they perform a clean-up of the current task. In the case of placing cones, if the first responder is carrying a cone he / she would quickly place the cone in the correct location or put it back before proceeding to the next task.

3.3. Building Additional Objectives for EMS and Police Roles

Currently a user can take on the role of EMS or police, however specific events and circumstances have not been built in the Simulation to make these roles rich and engaging. Pedestrians that are reporting causalities will approach fire personnel only, and playing the role of EMS currently doesn't allow you to tend to injured persons. Playing the role of a Police Officer also doesn't offer a rich user experience. We need to program random events and specific objectives for these roles. These could include:

- Crowd control.
- Traffic control.
- Controlling access to dangerous areas and setting up barricades.
- Preliminary investigation of the secondary event that could lead to apprehending suspects.
- Dealing with defiant pedestrians.
- Dealing with looters during the chaos.

3.4. Enhancements to Vehicular Traffic

Algorithms will be developed which create much more realistic traffic flows throughout the City. Vehicles will respond realistically to other close-by vehicles moving in parallel down one way streets, and will also respond to traffic lights. Additionally, vehicular traffic will be much more sensitive to first responder vehicles such as Ambulances, Police Cars and Fire Apparatus. Drivers of these vehicles will understand that they need to move out of the way for these vehicles and provide space. Coupled with the Real-Time Supervisory Control, Supervisors will have the ability to cause vehicular accidents due to the prevailing chaos in the areas where the train derailment and secondary van explosions have occurred.

3.5. Virtual Reality (VR) Enhancements

To make the Simulator much more immersive and create those conditions necessary to make the user feel like they are actually within the Virtual Environment, we feel that the integration of the Oculus Rift is an absolute necessity to achieving these objectives. Users will have available to them a stereoscopic 3D display with head tracking and position

tracking. The 3DInternet team will create the Software required to communicate with the Oculus Rift so that real-time rendered images from the left and right eye can be sent directly to the VR headset, and head tracking and position tracking can be retrieved and applied to the transform of the virtual camera within the 3D Virtual Environment. Once the Software is in place and functioning with the rest of the System, the user will be able to look around the Virtual Environment just like in the real-world. The combination of the separate left and right eye real-time rendered imagery on the stereoscopic display, will allow users to perceive "depth" inside the Virtual Environment.

3.6. Advanced Performance Monitoring with Persistent Storage

The current reporting system within the Simulation will receive a full upgrade, and in addition to simply providing a report of correct / incorrect actions within the Simulation, will also be continually monitoring the actions and reaction times of participants. A set of key performance indicators will be identified and then tracked from the start of a session right through to its conclusion. Supervisors will be able to leverage the output of the Advanced Performance Monitoring System so that training can be targeted to those specific areas requiring improvement.

All performance monitoring information will be forwarded to a back-end database for persistent storage and later retrieval. Supervisors using a Graphical User Interface screen built into the Real-Time Supervisory Control, will be able to access the back-end database and lookup any past training session to see exactly what transpired and the output of the Performance Monitoring.

The Advanced Performance Monitoring System (APMS) will provide a host of other metric measuring capabilities to Instructors and Supervisors. The APMS tracks all actions and behaviors within SE sessions and allows Instructors to see quite clearly how participants are performing by measuring certain predefined "key performance indicators". Instructors can then revise their training methodologies and provide more emphasis in those areas which appear to be problematic for trainees. Further sessions within the SE will then provide additional performance reports and measurements on key performance indicators. The graphing / charting visualizations within the AMPS will clearly show the increase / decrease on key performance indicators as a function of time. If Instructors see these increasing, then clearly the sessions within the SE are providing a training benefit.

4. Conclusion

The First Responder Immersive Training Environment (FRITSE) provides first responders, incident commanders etc. with a realistic and engaging tool to prepare these kinds of users for hazardous scenarios. In particular, users will experience those conditions representative of a train derailment involving the release of a toxic industrial material and a van explosion incident involving the possible release of a hazardous substance into the atmosphere. Working together in teams, end users will be able to apply their knowledge as first responders to treat injured persons, perform decontamination and fight the resulting train derailment fire. The work currently performed allows first responders to run the SE in both single user and multi-user modes. The artificial intelligence built into the SE allows for other non-player first responders such as firefighters, police and EMS to play their roles within the simulation of a CBRNE incident, and to also take instructions from incident commanders when necessary. This creates the sense that users are not alone, and that in fact, they are part of the wider tri-services team and are coordinating their actions as part of the response effort.

Our future work in this Simulation Product will consist of improving those parts which are critical in the functionality and marketability of the Product. Components such as the Artificial Intelligence Engine which drives the behavior of NPCs and the corresponding Task Library offer significant value to future products, as do the Multi-User Engine and corresponding Master Server with Real-Time Supervisory Control. The FRITSE provides a stable and extensible framework for additional first responder training scenarios as well as scenarios for other types of products which require "training within teams" and "coordinated response". Efforts will also be placed in upgrading the performance monitoring aspect of the SE so that key performance indicators can be measured and areas that require additional training can be identified.